## Question 3

1. Plot below shows the discrete plot of impulse response (h[n]).



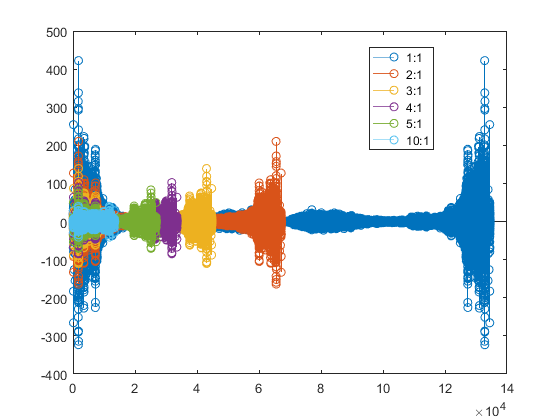
Result was confirmed with matlab as well, by looping over the impulse vector and finding the index where the first non-zero value occurs.

Frequency is 16000 Hz, so the delay = 149/16000 = 0.0093 seconds. Speed of sound = 340 m/s, so distance between microphone and the person is d = 340\*0.0093 = 3.1662 m.

1. Sound still audible after convolution, although there is some noise noticeable. A background noise can be heard which seems to have degraded the sound quality of the original audio. SHOROUQ!! Can you listen to both and give a better description?
2. An echo of the original sound can be heard.
3. The sound is played backwards by reversing the original sound vector. This is achieved by using the flipud in Matlab. Playing the backwards signal resulted in gibberish.

|  |  |
| --- | --- |
| Frequency | Comments |
| 13000 | The sound seems slower and the voice is now thick, low-pitched voice |
| 14500 | The sound is quite similar to the original but still slow, quite thick, low-pitched voice |
| 17000 | The sound is quite similar but is a faster, higher pitched version of the original |
| 18500 | The sound is much faster and higher pitched version of the original, and seems much higher than the previous frequency |
| 20000 | At this frequency, the sound is way high pitched and much faster than the original |

1. The plot below shows the Fast Fourier Transform (FFT) plot, comparing the original signal, with the sub-sampling signals

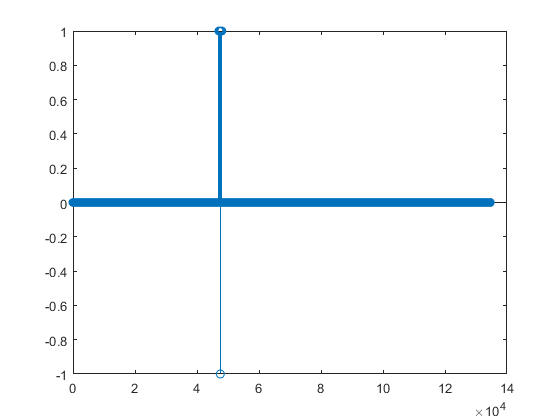


|  |  |
| --- | --- |
| Sub-Sample ratio | Ratio |
| 2:1 | The sound is very similar to the original with some minor losses in the audio |
| 3:1 | This sound is also similar to the original, but the signal seems more lossy now |
| 4:1 | This sound is more lossy than before, with the sound almost resembling a muffled audio |
| 5:1 | This sound is more muffled than before with the audio almost not bearable in low volume |
| 10:1 | This sound has the most losses, having the greatest muffled audio |

1. The following results were obtained after quantization:

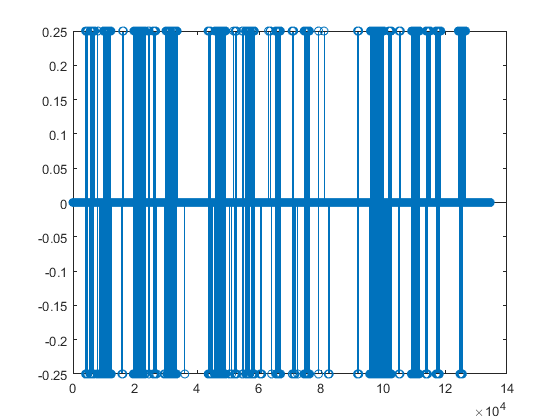
**1-bit quantization:**

The graph below shows the discrete plot of the 1-bit quantized signal. In this case, nothing could be heard apart from a slight noise at the at a specific time, which corresponds to the plot



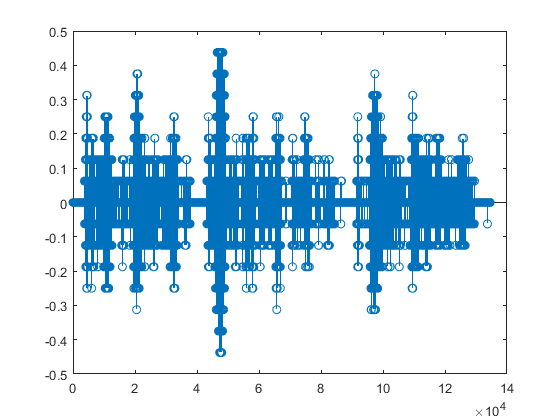
**2-bit quantization:**

The graph below shows the plot for the 2-bit quantized signal. In this case, most of the signal was cut-off (could not be heard) with background noise, severely hampering the quality. However, some parts of the original could be heard, albeit with the noise



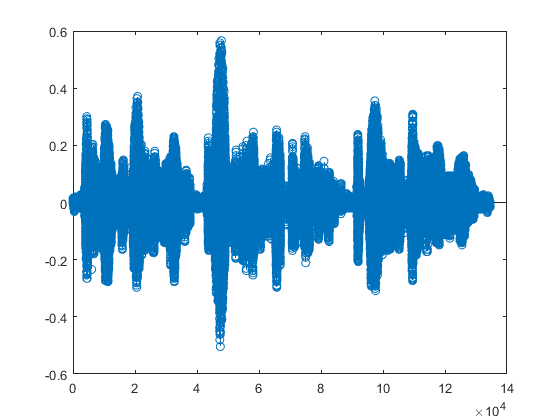
**4-bit quantization:**

The graph for 4-bit quantization is as shown below. In this case, the original signal could be heard without any cut-offs, however there was noticeable background noise.



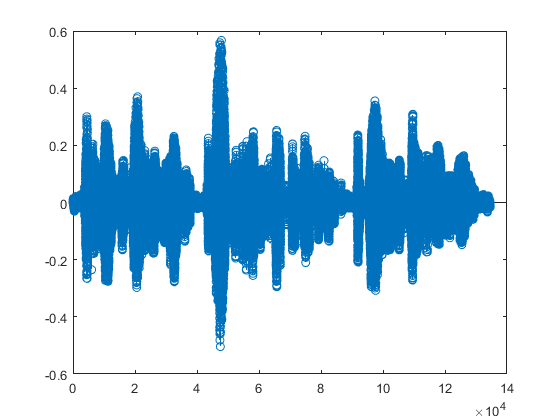
**8-bit quantization:**

In this case the sound was very clear, almost close to the original. Some low and minor noise could be heard with the signal at very specific points and not throughout the audio playback, as was the case with 4-bit quantization. The discrete plot is shown below, which is almost the same as the discrete of the original signal.



**16-bit quantization:**

In this case the sound quality was the same as the original and no noise could be heard. The plot is shown below, which is now more closer and better in shape compared to the original signal’s plot.



## Question 5

1. Here is an example of 4 equations with 4 unknowns where the real and mod2 solutions differ

Solving the above four equations yields the following results in base-10: a = -1, d = 1,